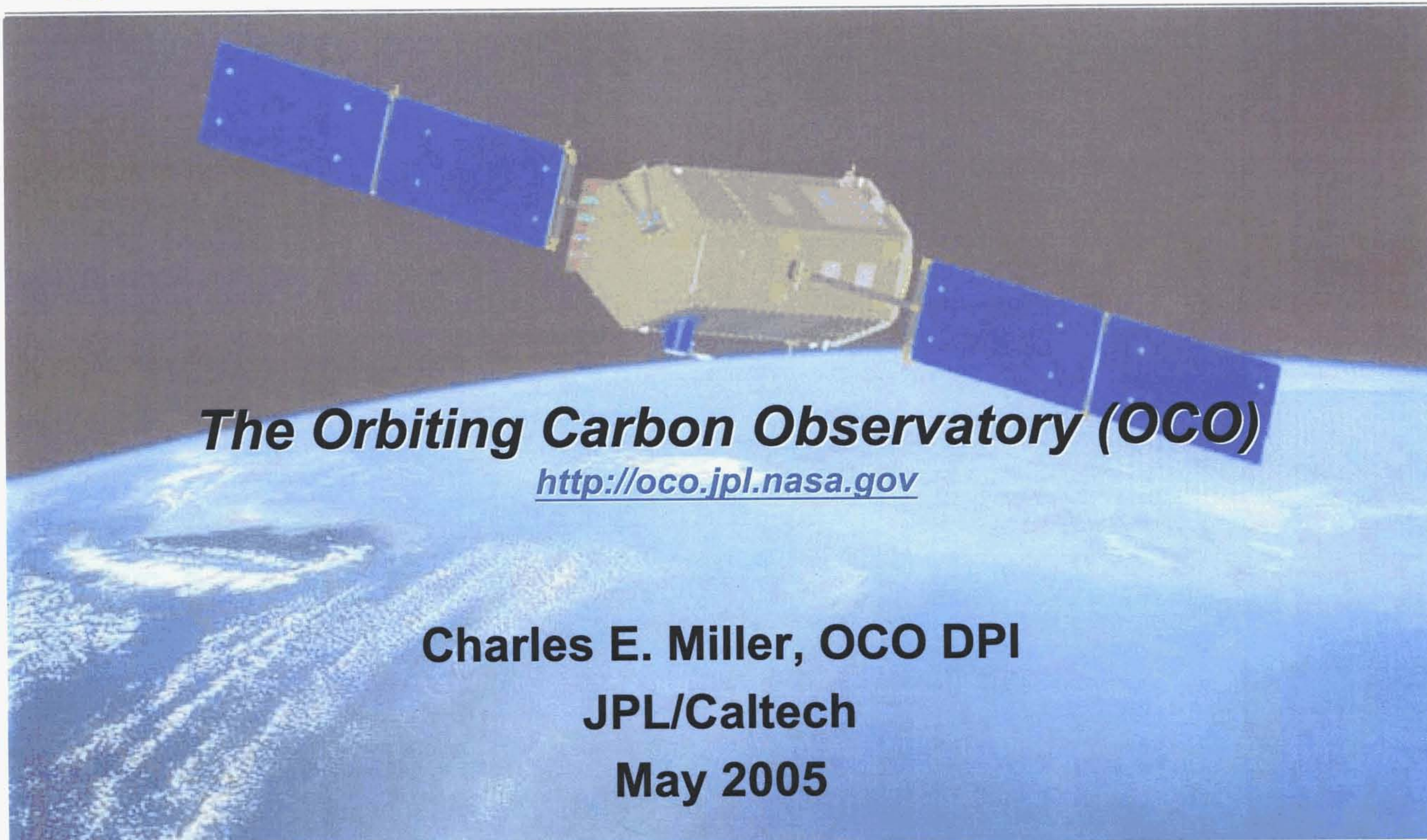
# GOSAT SYMPOSIUM



# The Orbiting Carbon Observatory (OCO)

http://oco.jpl.nasa.gov


## Charles E. Miller, OCO DPI

## JPL/Caltech

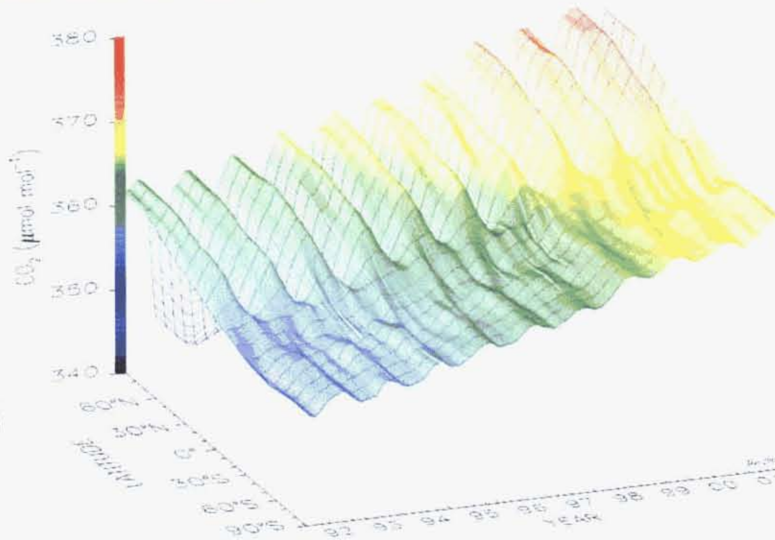

## May 2005

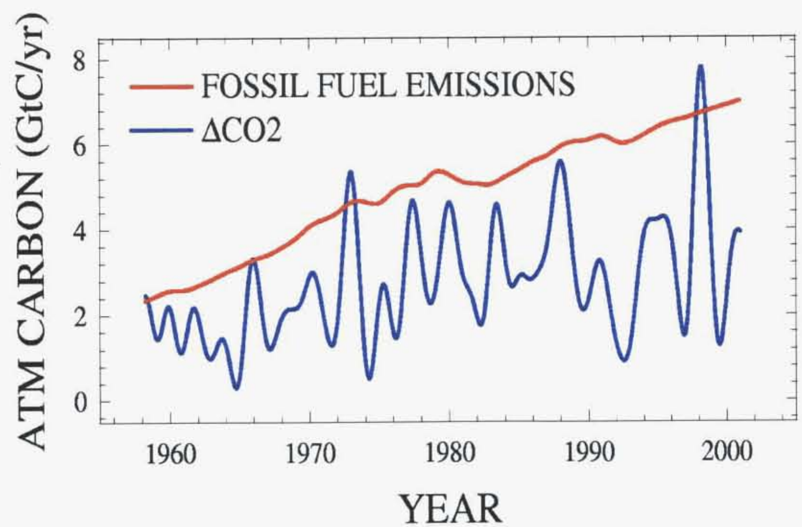


JPL Orbital Hamilton Sundstrand A United Technologies Company

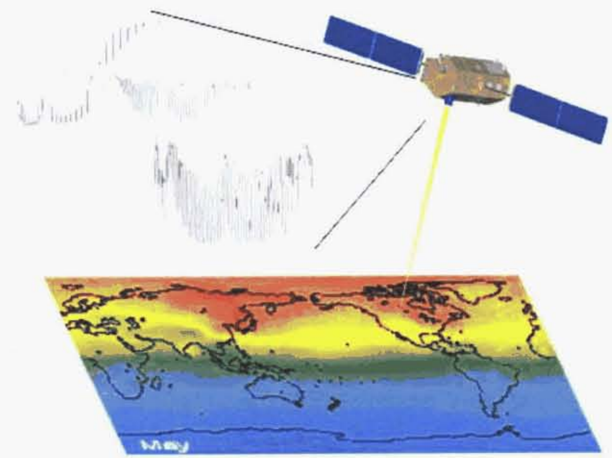
# What Processes Control $CO_2$ Sinks?

- **Carbon dioxide ($CO_2$) is the primary anthropogenic greenhouse gas**
  - **The $CO_2$ concentration has increased by ~25% from ~280 to 375 ppm since the beginning of the industrial age**
- **Only half of the $CO_2$ produced by fossil fuel combustion in the past 30 years has remained in the atmosphere.**
  - **Where are the sinks?**
- **Outstanding Issues:**
  - **Why does the atmospheric buildup vary substantially with uniform emission rates**
  - **What are the relative roles of $CO_2$ sinks**
    - Oceans vs land ecosystems
    - North American and Eurasian sinks?
  - **How will carbon sinks respond to climate change?**

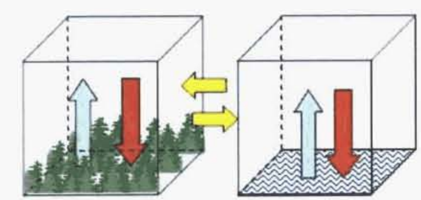


# The Orbiting Carbon Observatory (OCO)



- **OCO will measure $CO_2$ from space with the precision, resolution, and coverage needed to quantify $CO_2$ sources and sinks**
  - Simultaneous spectroscopic observations of $CO_2$ and $O_2$ used to estimate the column integrated $CO_2$ dry air mole fraction, $X_{CO2}$
  - Precision: ~1 ppm (0.3%) on regional scales
  - 1:15 PM polar orbit, 16 day repeat cycle

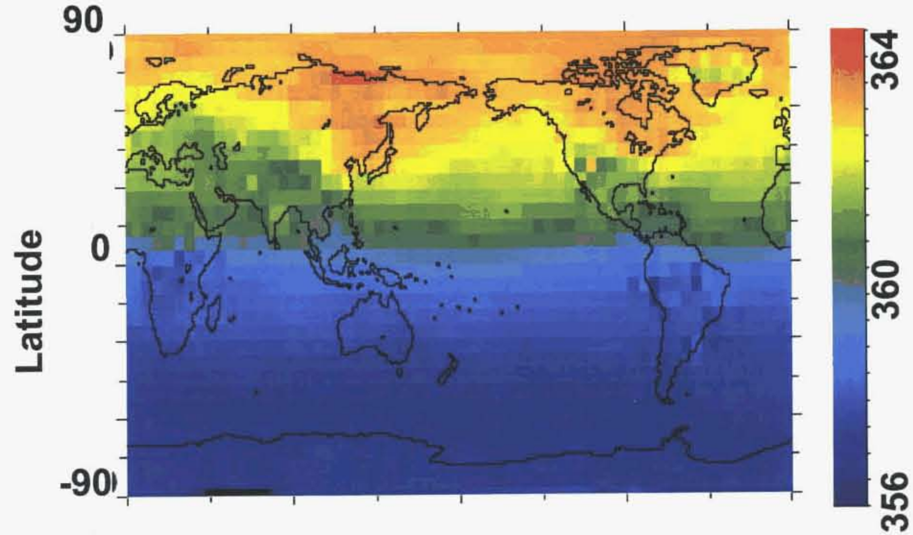



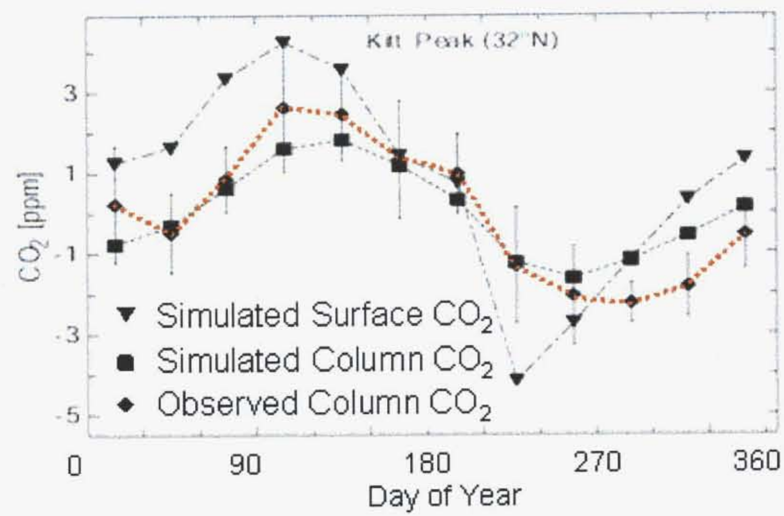
- **Team Members**
  - Principal Investigator: David Crisp, JPL
  - Project Manager: Rod Zieger, JPL
  - Instrument provider: Hamilton Sundstrand
  - Spacecraft provider: Orbital Sciences Corp.
  - International Science Team
- **Launch date: mid 2008**

# *Precise $CO_2$ Measurements Needed to Constrain Surface Fluxes*

**Space-based $X_{CO2}$ measurements with precisions of 1–2 ppm (0.3–0.5%) on regional scales will:**

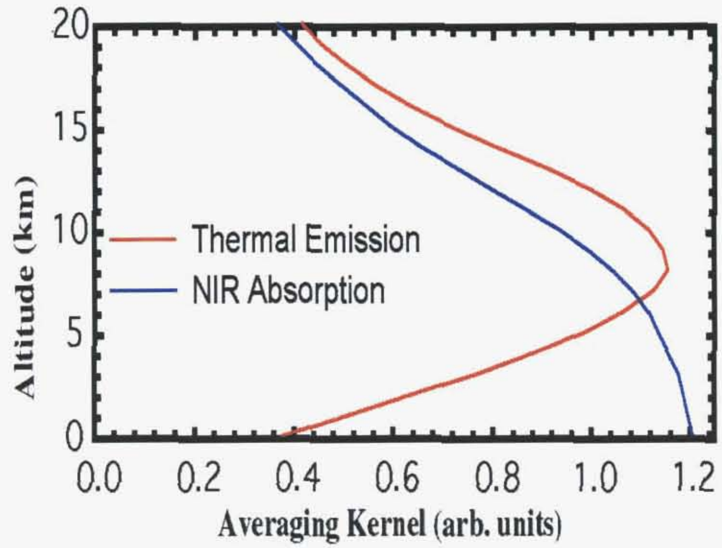
- Resolve pole to pole $X_{CO2}$ gradients on regional scales
- Resolve the $X_{CO2}$ seasonal cycle in the Northern Hemisphere
- Improve constraints on $CO_2$ fluxes (sources and sinks) compared to the current knowledge
  - **Reduce regional scale flux uncertainties from >2000 gC $m^{-2}$ $yr^{-1}$ to < 200 gC $m^{-2}$ $yr^{-1}$**
  - **Reduce continental scale flux uncertainties below 30 gC $m^{-2}$ $yr^{-1}$**

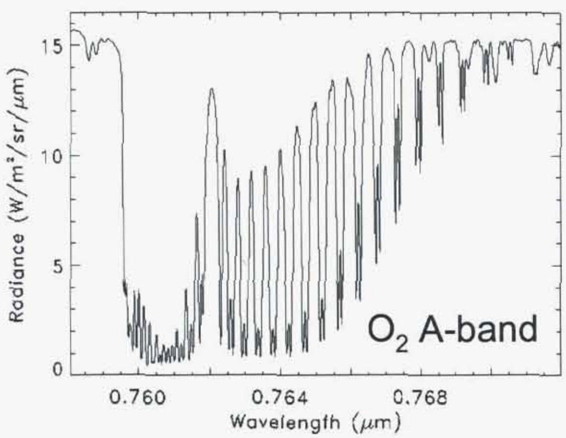


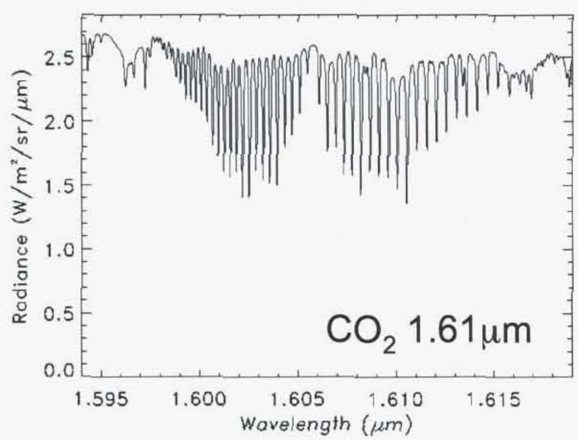
# *Making Precise $CO_2$ Measurements from Space*

- **High resolution spectra of reflected sunlight in near IR $CO_2$ and $O_2$ bands used to retrieve the column average $CO_2$ dry air mole fraction, $X_{CO2}$**
  - **1.61 μm $CO_2$ bands – Column $CO_2$ with maximum sensitivity near the surface**
  - **$O_2$ A-band and 2.06 μm $CO_2$ band**
    - Surface pressure, albedo, atmospheric temperature, water vapor, clouds, aerosols
- **Why high spectral resolution?**
  - **Enhances sensitivity, minimizes biases**

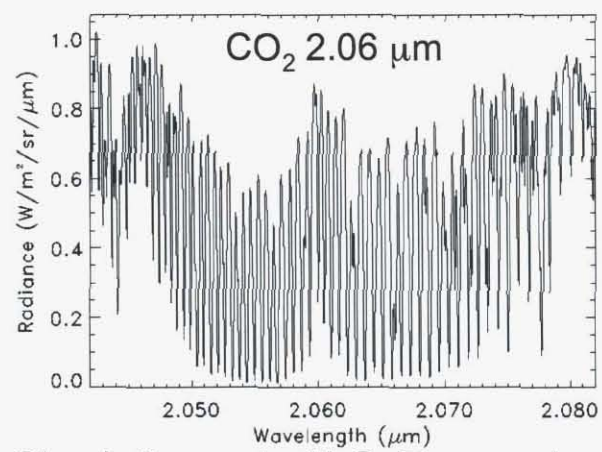



Clouds/Aerosols, Surface Pressure




Column $CO_2$

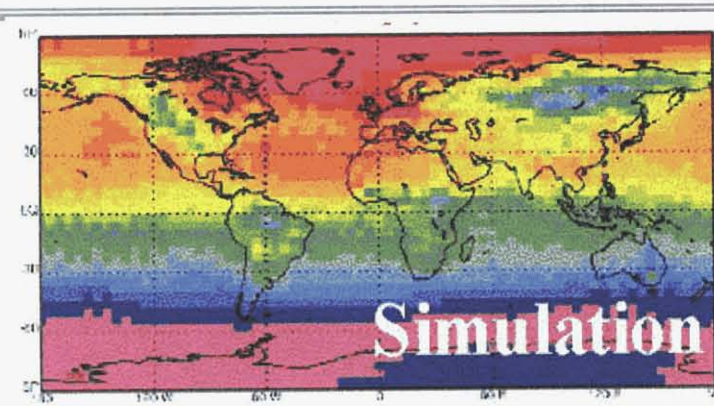


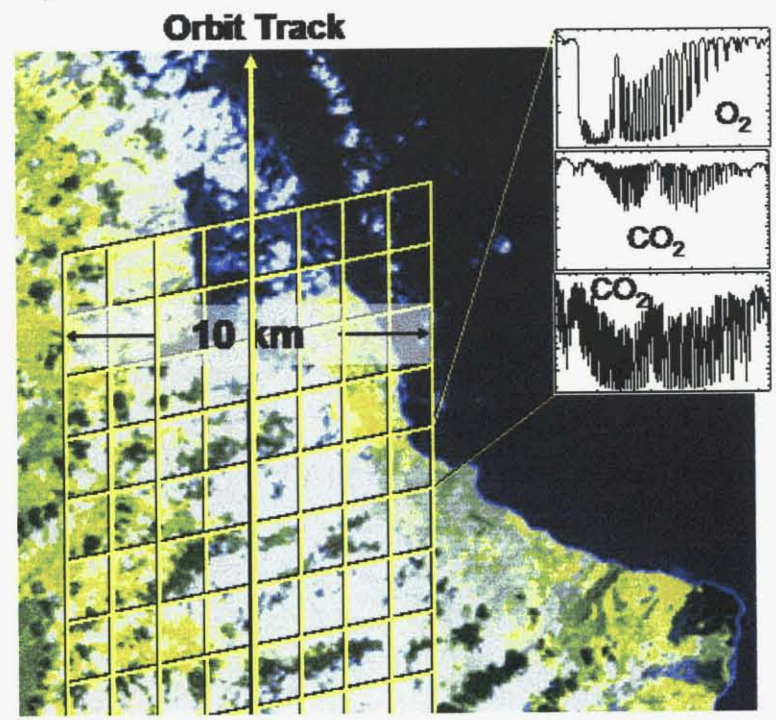

Clouds/Aerosols, $H_2O$, Temperature

# OCO Spatial Sampling Strategy

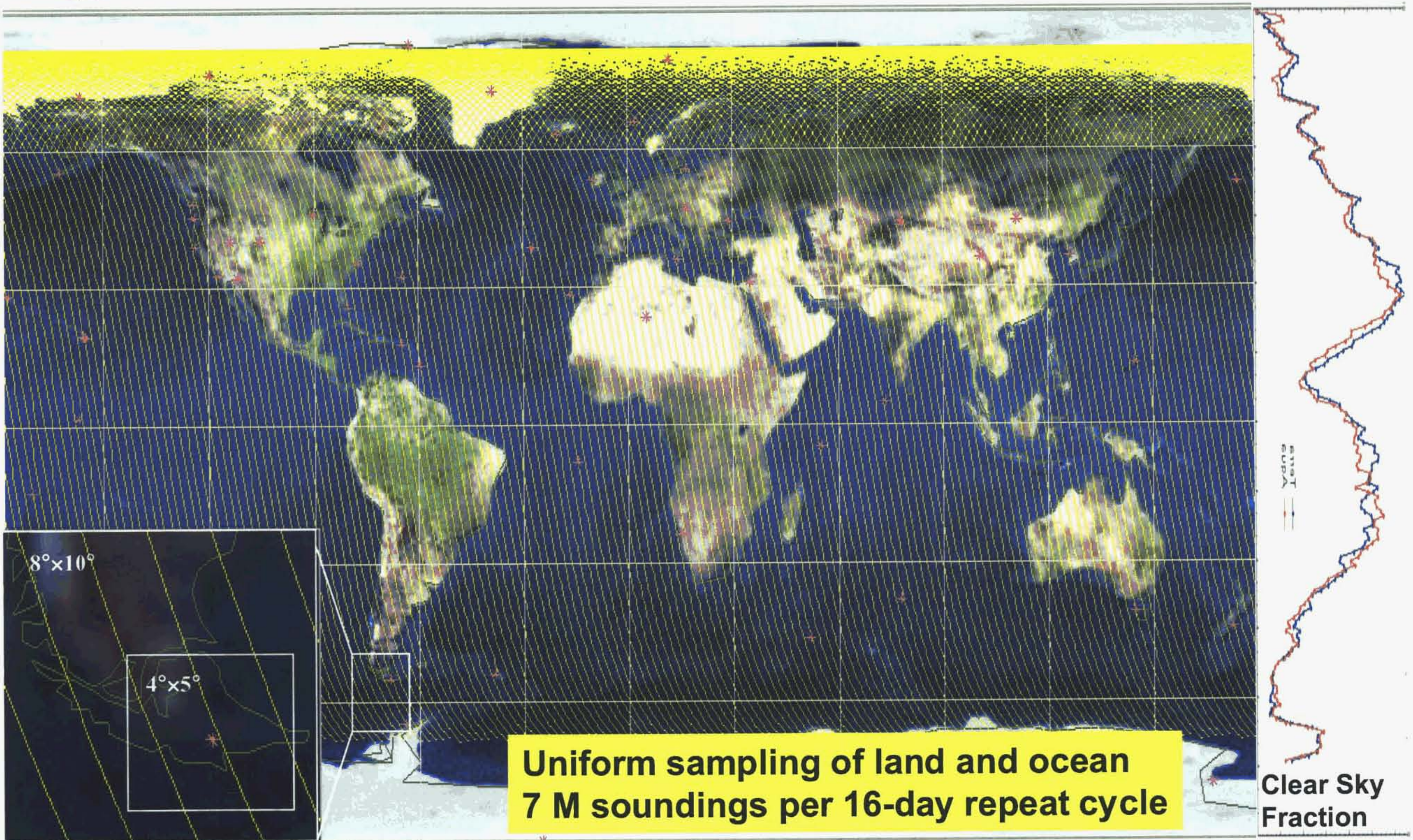
**The OCO spatial sampling strategy has been designed to provide precise, bias-free estimates of $X_{CO2}$ on regional scales at monthly intervals**

- Contiguous sampling not needed
  - Chemical Transport Models infer sources and sinks from spatial and temporal gradients in $X_{CO2}$
    - Have resolutions of 1° to 5°
  - Winds transport $CO_2$ over large areas as it is mixed through the column
- $X_{CO2}$ soundings must be collected at high spatial resolution
  - Maximizes the number of cloud-free samples in partly cloudy regions
  - Minimizes errors due to spatial inhomogeneities within each footprint



# OCO Sampling over a 16-Day Repeat Cycle





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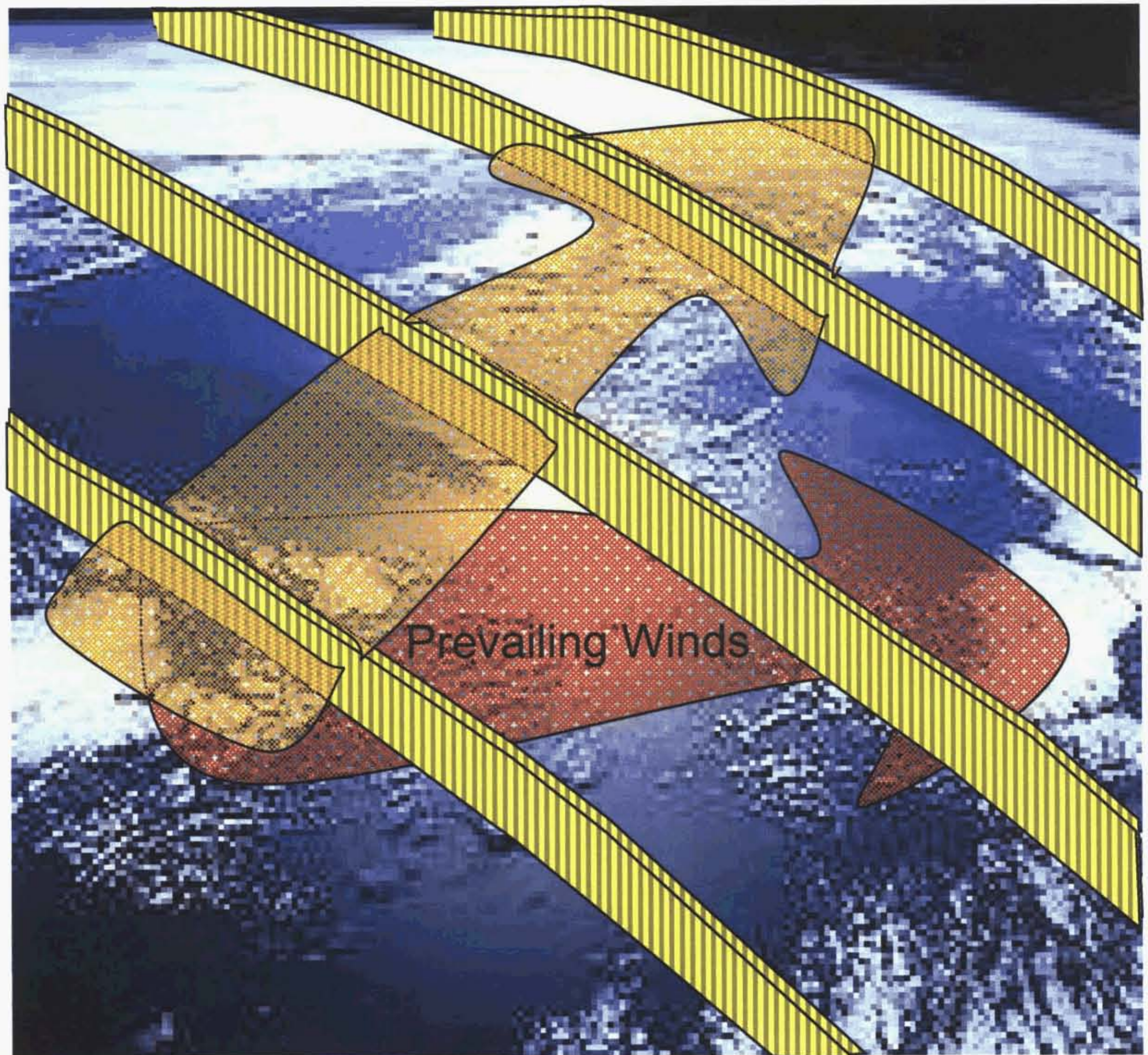
# Value of Column Measurements

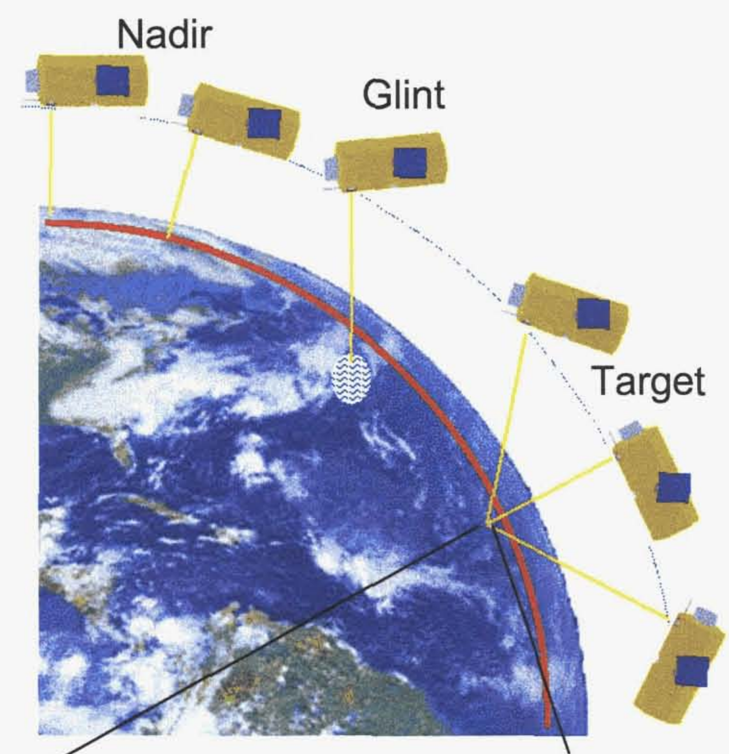



$CO_2$ Column Measurements complement the existing surface measurement nework.

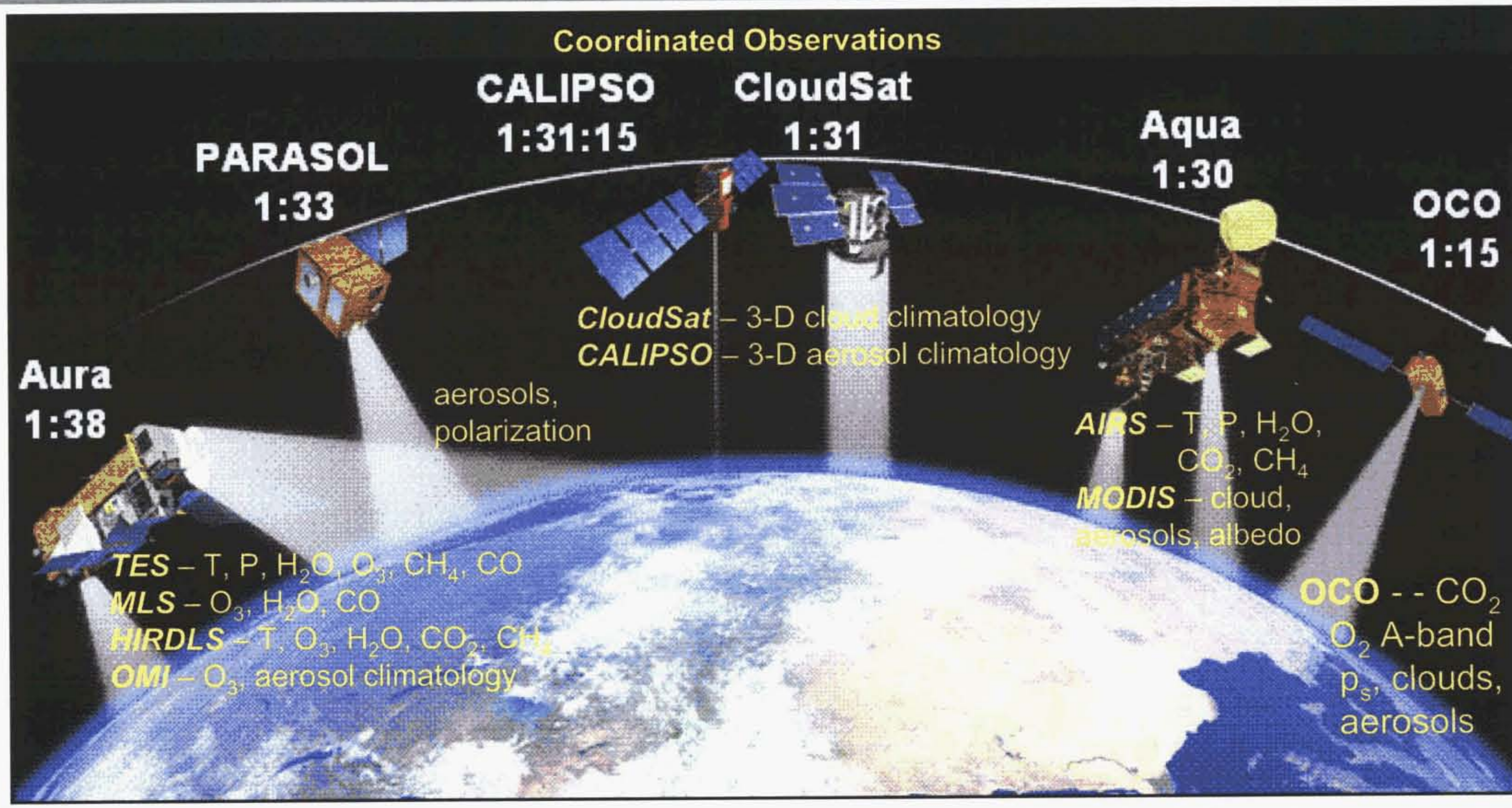
$CO_2$-rich (poor) plumes can be carried over surface measurement sites, but will not be missed by high density column measurements like those to be collected by OCO.

# *OCO Observing Modes*

- **Nadir Observations: tracks local nadir**
  - \+ Small footprint (< 3 $km^2$) isolates cloud-free scenes and reduces biases from spatial inhomogeneities over land
  - \- Low Signal/Noise over dark ocean
- **Glint Observations: views "glint" spot**
  - \+ Improves Signal/Noise over oceans
  - \- More interference from clouds
- **Target Observations**
  - – Tracks a stationary surface calibration site to collect large numbers of soundings
- **Data acquisition schedule:**
  - Alternate between Nadir and Glint on 16-day global sampling repeat cycles
  - Acquire ~1 Target observation each day



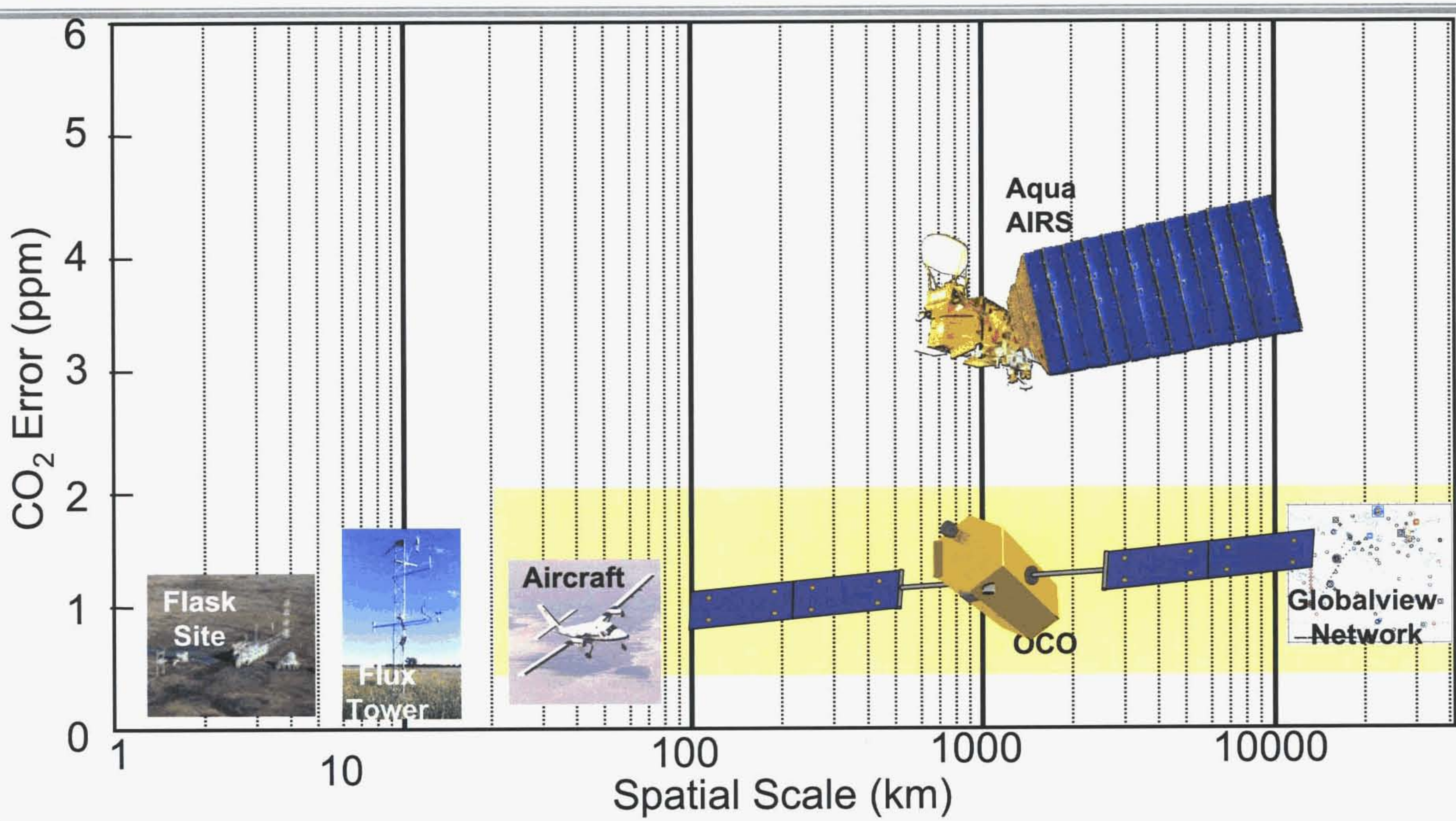

# OCO Will Fly in the A-Train




**OCO files at the head of the A-Train, 15 minutes ahead of the Aqua platform**

- 1:15 PM equator crossing time yields same ground track as AQUA
- Near noon orbit yields high SNR $CO_2$ and $O_2$ measurements in reflected sunlight
- $CO_2$ concentrations are near their diurnally-averaged values near noon
- Maximizes opportunities of coordinated science and calibration activities

# OCO Fills a Critical Measurement Gap

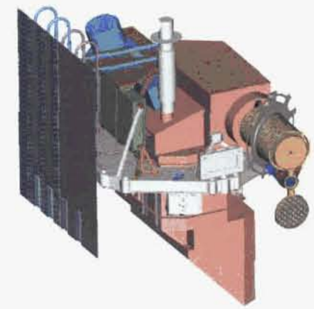



OCO will provide precise global measurements of $X_{CO2}$ over the range of spatial scales to reduce $CO_2$ flux uncertainties by up a factor of 100 on regional to continental scales.

# *Mission Architecture*

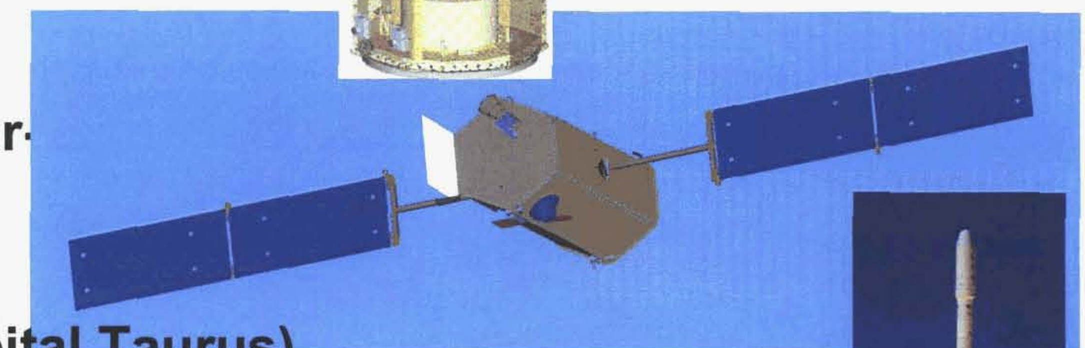
## Single Instrument (Hamilton Sundstrand)

- **Incorporates 3 bore-sighted, high resolution, grating spectrometers**
  - **$O_2$ 0.765 μm A-band, R=17,000**
  - **CO2 1.61 μm band, R=20,000**
  - **CO2 2.06 μm band R=20,000**



## Dedicated Bus (Orbital LEOStar-

- Heritage: GALEX, SORCE



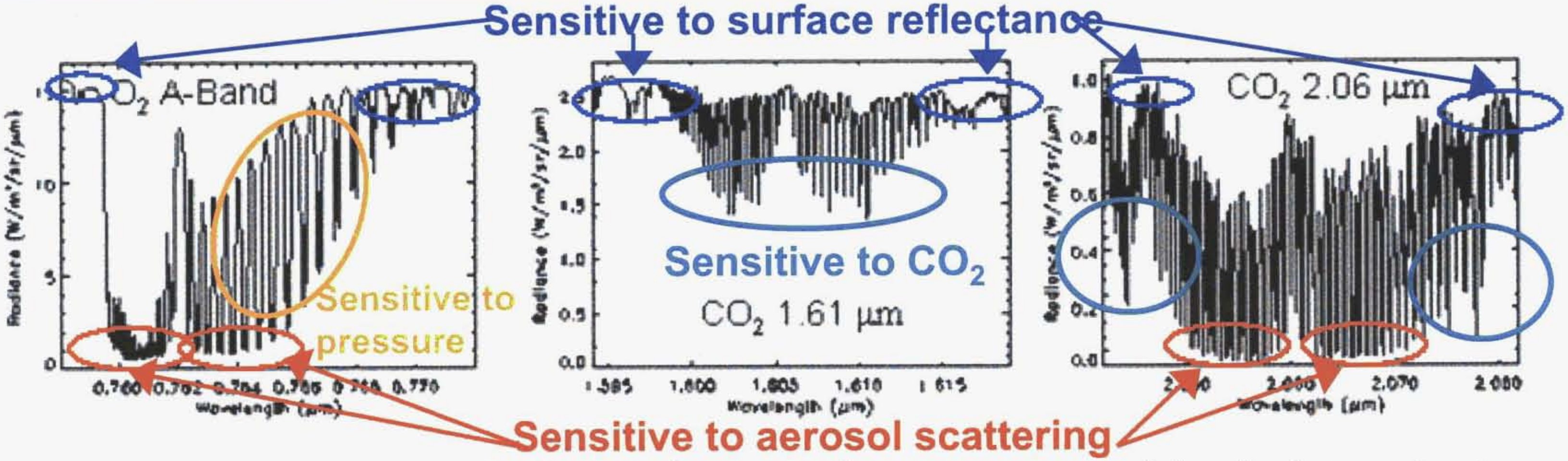
## Dedicated Launch Vehicle (Orbital Taurus)

- October 2007 Launch from Vandenburg

## Mission Operations

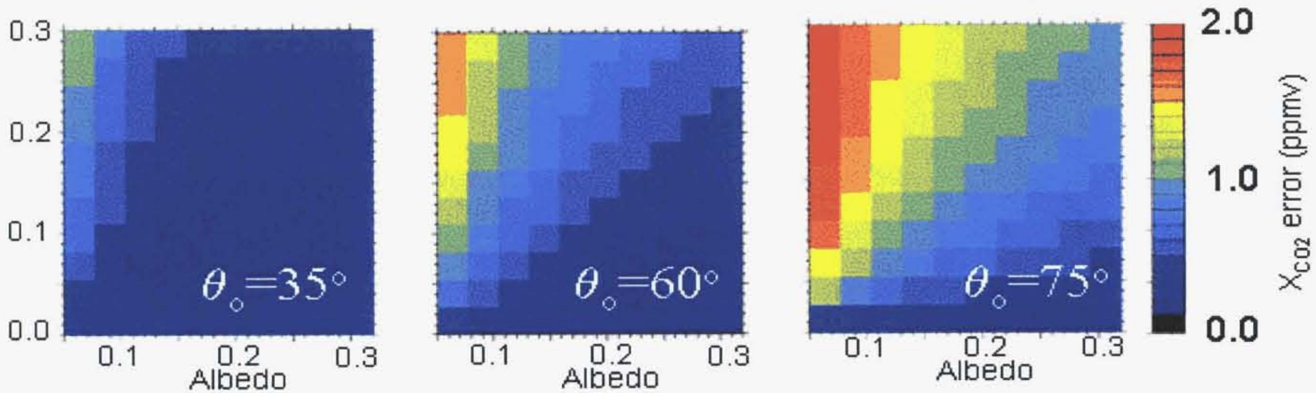
- Mission Operations (Orbital MOC)
- High latitude station for downlink station

# How Well Can the OCO Measure $X_{CO2}$? -Validation of the OCO Retrieval Algorithm



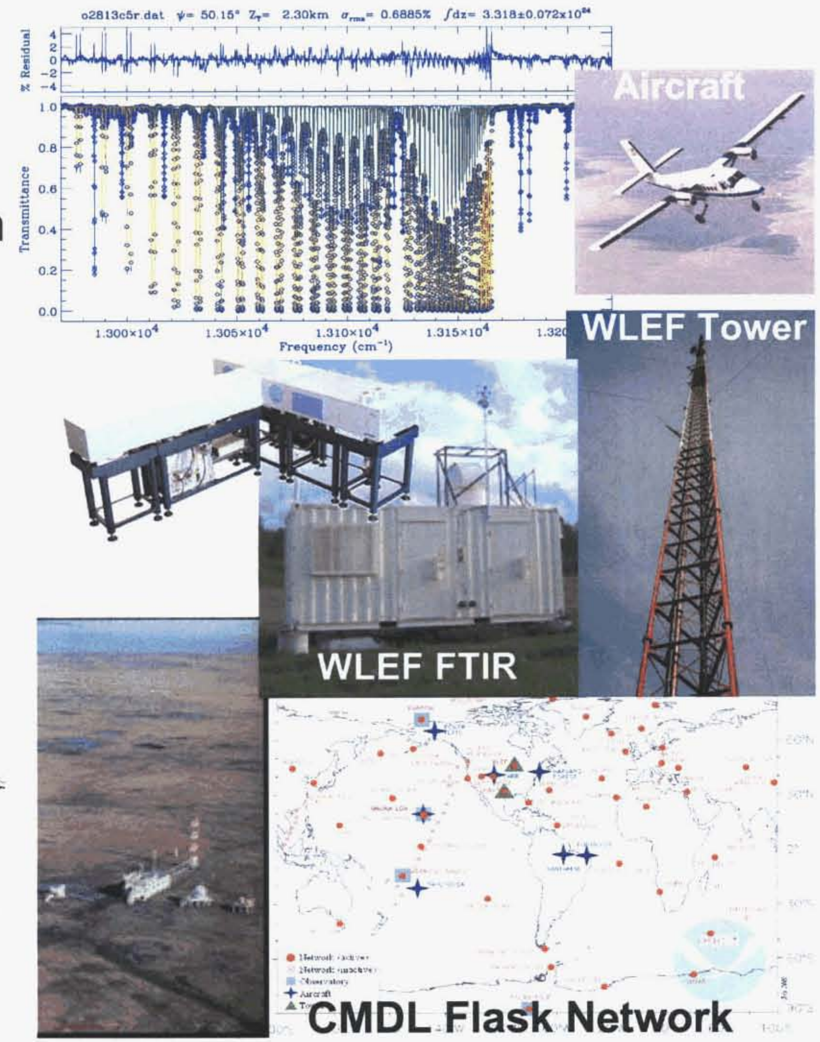

***Combining high spectral resolution and spectral coverage provides independent constraints on surface pressure, aerosols, surface reflectance, and $CO_2$, minimizing systematic errors.***

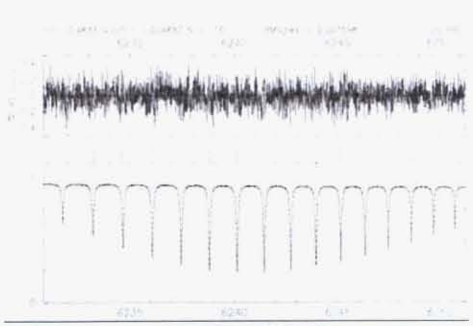
*$X_{CO2}$ retrieval errors are shown as a function of albedo and aerosol optical depth for 3 solar zenith angle, $\theta_o$ Single-sounding $X_{CO2}$ retrieval errors exceed 2 ppm (0.5%) only for extreme cases ($\theta_o$>75°, $\tau$ > 0.3)*

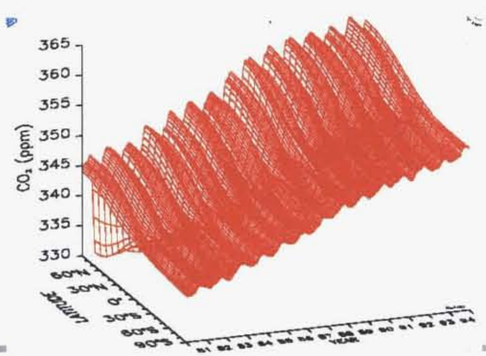


# Validation Program Ensures Accuracy and Minimizes Biases

- Ground-based in-situ measurements
  - NOAA CMDL Flask/Tower Network
- Aircraft measurements of $CO_2$ profile
  - Coordinated with COBRA, INTEX, follow-on
  - CNRS Aerocarb
- Uplooking FTS measurements of $X_{CO2}$
  - Measure same bands as flight instrument
  - 3 new and 4 upgraded stations funded by OCO
- Laboratory spectroscopy
  - **Spectral line databases for $CO_2$, $O_2$**





# Summary

- $CO_2$ is the principal human generated driver of climate change
- Accurate forecasting of future climate requires an improved understanding of the global carbon cycle and its interaction with the climate system
- The Orbiting Carbon Observatory (OCO) will make global, space-based observations of atmospheric $CO_2$ with the precision, resolution, and coverage needed to understand sources and sinks
- OCO data will provide critical information for decision makers
  - *Scientific basis for policy formulation*
  - Guide for carbon management strategies and Treaty monitoring

**Climate Forcing/Response**

| | | |
|---|---|---|
| •$T/H_2O/O_3$ | ☑ | AIRS/TES/MLS |
| •Clouds | ☑ | CloudSat |
| •Aerosols | ☑ | CALIPSO |
| •$CO_2$ | ☑ | OCO |